Section 2.6

Transfer Devices

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Transfer Devices

2.6.0. Introduction

2.6.0.1. Transfer Systems Objective

The current process design is a combination of semi-batch and batch unit operations, and as such, there are no identified process requirements for a transfer device to provide emergency fluid transfers.

Where transfer devices are required to maintain; confinement of fluids, process performance or cooling services, these are addressed in Sections 2.1 Shielding and Confinement, 2.5 Utilities and Services, or 2.8 Unit Operations respectively.

2.6.0.2. Fluid Transfer Systems

The liquid transfer devices applied to radioactive systems are gravity transfers (with valved isolation/flow diversion), mechanical pumps (with valved isolation / flow diversion), steam ejectors, reverse flow diverters (RFD’s) or Diode Pumps with a breakpot to give a continuous flow. Where an accurate flow is required, this is achieved using an RFD feeding a constant volume feeder (CVF). A ‘decision tree’ was developed that enabled the identification of required transfer devices for given duties.

2.6.0.2.1. Mechanical Pumps

For radioactive streams, mechanical pumps are only used when maintenance free fluidic transfer devices can not be utilized. Pumps are only incorporated when requirements exist to provide continuous transfers, high flowrates, and high pressures. Only equipment with a proven records of high reliability is proposed.

Potential faults addressed include overpressurization of the pump circuit, excessive flow causing the overfilling of recipient vessel, and the loss of service flow

2.6.0.2.2. Steam Ejectors

These items all require less maintenance, and are used in preference to pumps where possible. Only equipment with proven records of high reliability is proposed.

Potential faults addressed include; continued steam delivery after vessel is empty discharging active aerosol into the vessel ventilation system; challenging filters by active burden and potentially by moisture loading (wet filters will fail at lower ΔP); steam condensing in supply line creating a vacuum which can potentially cause active liquor to be drawn out of shielding and primary confinement; reverse flows of liquor after steam isolation, causing elevation of liquor beyond starting elevations and so risking its rising above primary shielding and confinement.

2.6.0.2.3. Reverse Flow Diverters and Diode Pumps

The main features (and potential faults) of RFD and Diode Pump systems are virtually identical. The only main exception being, that the single diverter valve (RFD nozzle) is replaced by two separate fluidic diodes. These items all require less maintenance, and are used in preference to pumps where possible. Only equipment with proven records of high reliability is proposed.

Normal operation of RFDs and Diode Pumps does not require the achievement of any particular safety function beyond utility confinement. A cabinet is provided to house the air handling system to achieve this. A number of fault conditions can however place demands on other ITS SSCs. Known fault conditions against which protection is required are:

- Over blow:
  Air is blown through the process liquor causing enhanced aerosol challenge to the vessel ventilation system

- Over suck:
  Air is sucked through the liquor in the charge vessel causing enhanced aerosol challenge to the vessel ventilation system.

- Over raise:
  The suction phase lifts liquor out of shielding and primary confinement.

- Cross blow:
  Liquor is pulled into one jet pump and an air liquor mixture expelled from the other, causing enhanced aerosol challenge to the vessel vent system.

2.6.0.2.4. Valves

Potential faults addressed include misrouting of liquids, backflow of activity into operating areas, overfilling of vessels, and loss of services.

2.6.0.2.5. Constant Volume Feeders

Potential faults addressed include; leakage of activity from CVF into the cell causing additional burden on the cell ventilation system, leakage of activity from the CVF into the operating area, excessive flow (backing up), low/no flow from CVF resulting in the overfillling of the CVF, and cross contamination into wash water system.

2.6.0.2.6. Breakpots

Potential faults addressed include; carry over of aerosols into the vessel ventilation system, and misrouting of liquids through flooding.

2.6.1. Constant Volume Feeders

2.6.1.1. Purpose

A CVF is used to meter an active liquor feed within a cell where activity levels preclude the use of more conventional metering devices such as pumps, and control valves. The CVF is used on the TWRS project to meter active feed to the nitric acid recovery system kettle reboiler at a fixed.

2.6.1.2. Description

A diagram of a typical CVF is shown in Figure 2.6-1.

A CVF consists of an enclosed tank which is maintained partially full of liquor and contains a rotating wheel which has hollow tubular spokes to which cylindrical buckets are attached. As the wheel rotates the buckets submerge and fill with liquid through an inlet hole at the end of each bucket. On surfacing, the liquid in the buckets and spokes drain back through the inlet holes whilst the remaining liquid below the inlet holes discharges down the spokes into a collection and discharge funnel.

The CVF is filled by a separate transfer device. In order to maintain a constant liquid level in the CVF the CVF is fitted with an overflow that drains back to the supply vessel. Discharge from a CVF is by gravity flow from the collection and discharge funnel.

2.6.1.3. Hazardous Situations

The normal operation of the CVF does not require the achievement of any particular safety function beyond confinement.

1. Leakage of activity from CVF into the cell causing additional burden on the cell ventilation system.

2. Leakage of activity from the CVF into the operating area resulting in the contamination of facility workers.

Figure 2.6-1. Typical Arrangement for CVF.

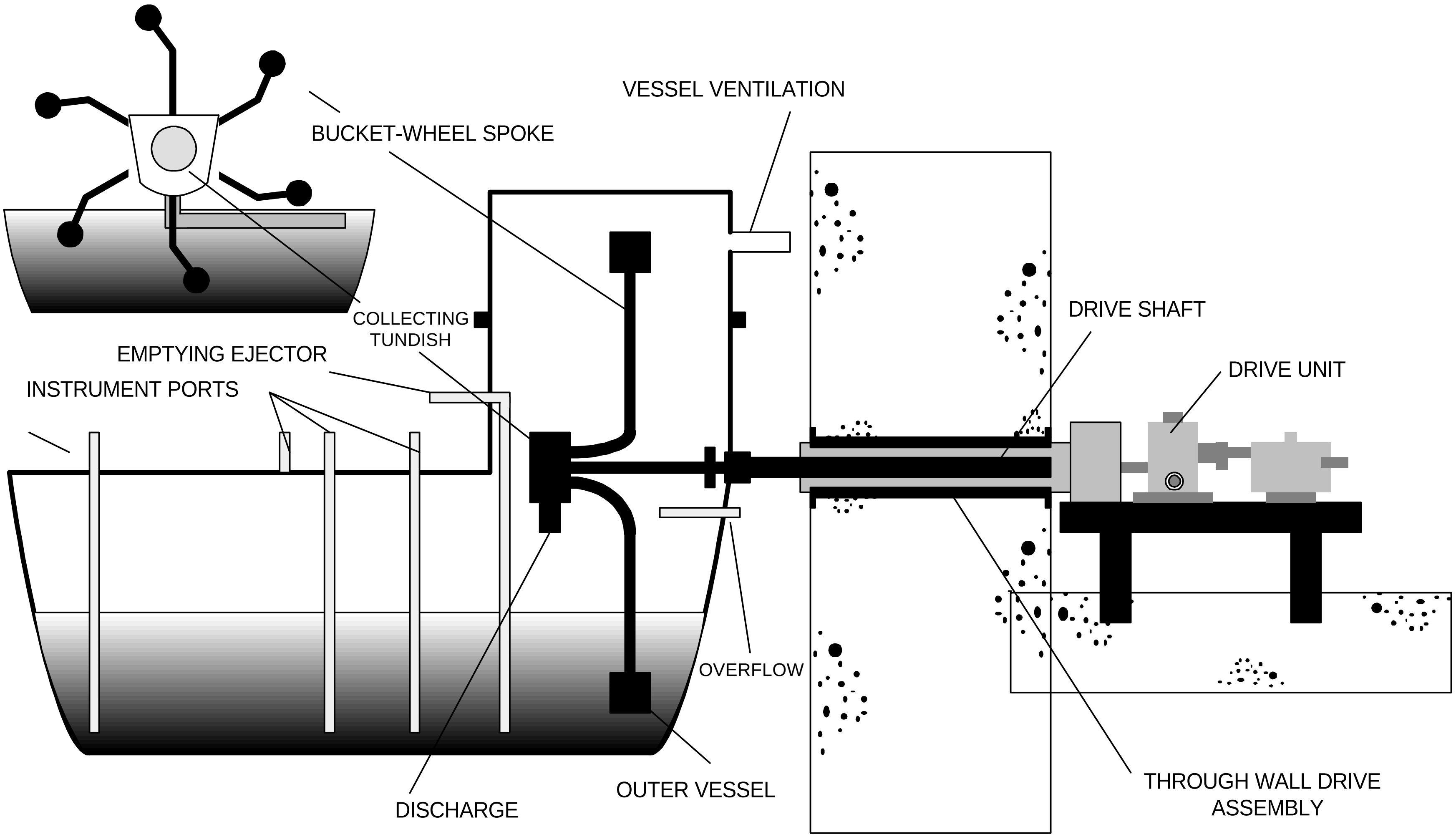


Table 2.6-1. Constant Volume Feeders

Fault	Important to Safety SSCs	Safety Function	Design Safety Feature
Leakage of activity from CVF into the cell causing additional burden on the cell ventilation system	Overflow pipework Vessel	To prevent the liquor in the CVF from flowing out through the drive shaft vessel interface. Primary confinement	Overflow is designed to cater for the maximum in-flow from the feed. Vessel integrity. See Vessel section.
	Shaft wiper seal	Prevent liquor travel along drive shaft	Passive
Leakage of activity from the CVF into the operating area resulting in contamination of workers	Mechanical seal (Through wall shaft seal)	Prevent activity from flowing from the CVF via the shaft into the operating area.	Passive

2.6.2. Reverse Flow Diverters

2.6.2.1. Purpose

The main features (and potential faults) of RFD and Diode Pump systems are virtually identical. The only main exception being, that the single diverter valve (RFD nozzle) is replaced by two separate fluidic diodes. RFDs provide proven maintenance free pulsed or metered transfer of active liquors or high solid content slurries. Fluidic devices transfer liquor or slurry streams for which an increase in temperature or an increase in dilution is not acceptable. Fluidic devices require low submergence within a process vessel and give the ability to significantly empty vessels, leaving only a small and predictable level of liquor.

2.6.2.2. Description

RFD pump operation is cyclic; hence the flow of liquor from the pump is not continuous. There are three phases in the cycle, namely suction phase, drive phase, and blowdown phase.

Figure 2.6-2 shows a typical RFD pumping system arrangement.

<u>RFD Nozzle:</u>

The nozzle, also termed the pumping element, is a passive fluidic device through which fluid enters the pump from the supply tank. The RFD operates by the entrainment principle and consists of two opposed nozzles; a symmetrical design is shown in Figure 2.6-3.

<u>Suction phase:</u>

The secondary automatic valve A is open, admitting air to the suction jet pump. Valve B is shut. Liquor is sucked from the supply tank through the RFD and into the charge vessel. The suction ejector is designed so that it cannot produce a vacuum capable of lifting liquor higher than a certain value known as the “suction lift”. After a short time the liquor reaches this height and stops and valve A is shut.

<u>Drive phase:</u>

When valve A is shut, valve B is opened, admitting air to the drive nozzle. Air passes through the nozzle and pressurizes the charge vessel. Liquor is forced across the RFD and into the delivery pipe. The delivery pipe is quickly filled with liquor which then flows into the delivery vessel.

<u>Blowdown phase:</u>

When the charge vessel is nearly empty valve B is shut, no means of air is supplied to either jet pump. The compressed air in the charge vessel passes back through the jet pump pair, down the vent pipe and into the vessel vent system.

Shortly after blowdown starts the pressure in the charge vessel falls below the delivery head and the flow of liquor into the delivery vessel is halted. The liquor in the delivery vessel then falls back down the pipe, across the RFD, and into the charge vessel. After a short time the pressure in the charge vessel falls to zero (gauge). The cycle is now complete.

The RFD suction and drive cycles can be controlled by either of the following systems.

Timed systems:

This system relies upon a simple pre-set timer control for drive and suction cycles. The timed intervals are established from the RFD system characteristics and data taken during commissioning. Timed cycles will be matched to the natural resonance of the RFD system to prevent loss of efficiency and eliminate possible charge vessel blow through to the ventilation system. The timed system will be enhanced with the addition of pressure transducers in the drive and suction lines which are used to monitor for the above problems.

Programmable systems:

This is a more complex control system. The line pressures of the drive and suction legs are constantly monitored to establish current liquor levels and combined with timed elements will provide a more accurate RFD control and additional protection against fault conditions.

2.6.2.3. Hazardous Situations

Normal operation of RFDs does not require the achievement of any particular safety function beyond utility confinement. A cabinet is provided to house the air handling system to achieve this. A number of fault conditions can however place demands on other ITS SSCs. Known fault conditions against which protection is required are:

Over blow:

Air is blown through the process liquor causing enhanced aerosol challenge to the vessel ventilation system

Over suck:

Air is sucked through the liquor in the charge vessel causing enhanced aerosol challenge to the vessel ventilation system.

Over raise:

The suction phase lifts liquor out of shielding and primary confinement.

Cross blow:

Liquor is pulled into one jet pump and an air liquor mixture expelled from the other, causing enhanced aerosol challenge to the vessel vent system.

The set of Important to Safety SSCs for the above hazardous situations (or faults) is provided in the following tables. The table also identifies the Safety function and the Design Safety Features.

Figure 2.6-2. Typical Arrangement of a Reverse Flow Diverter

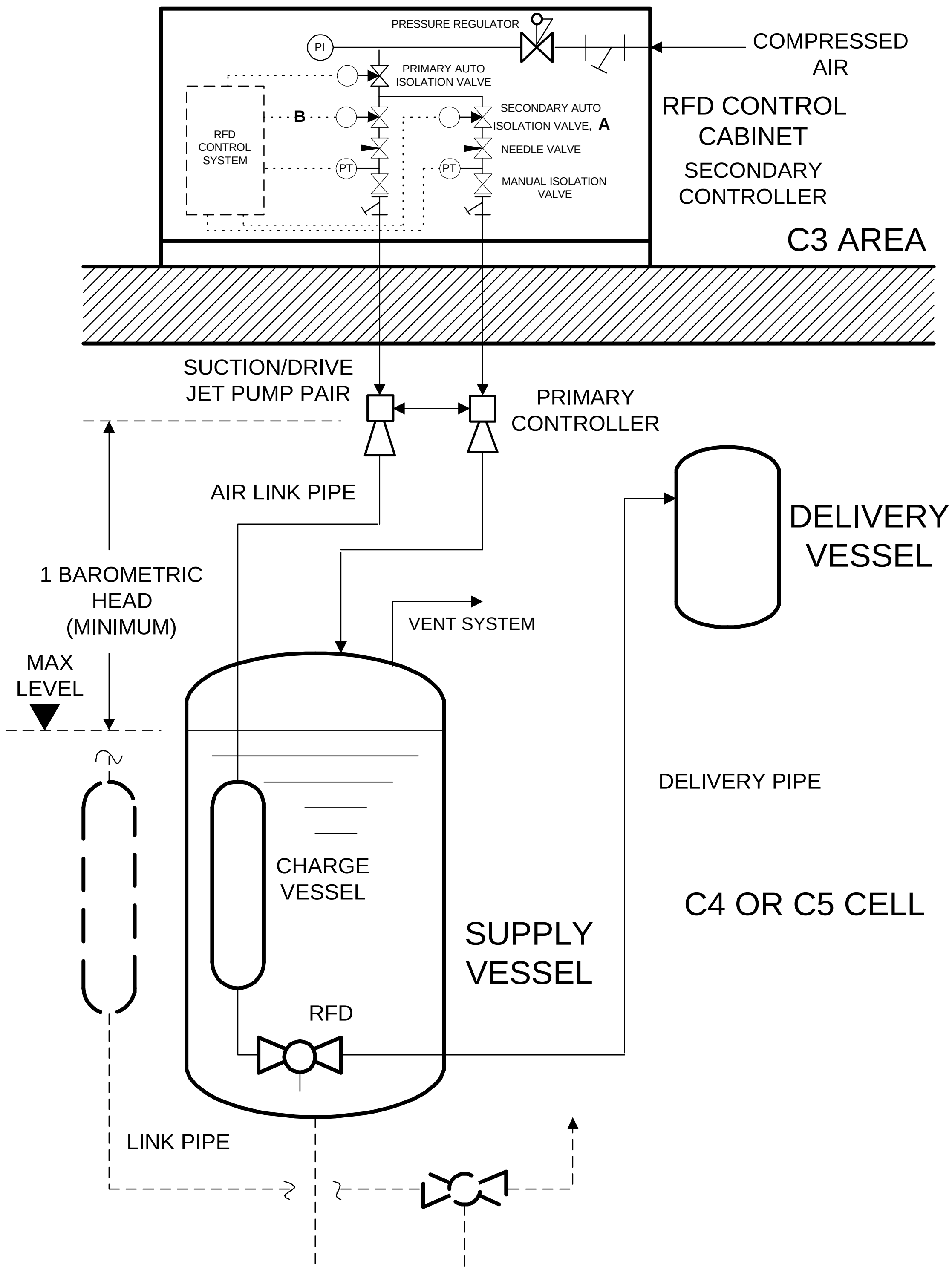
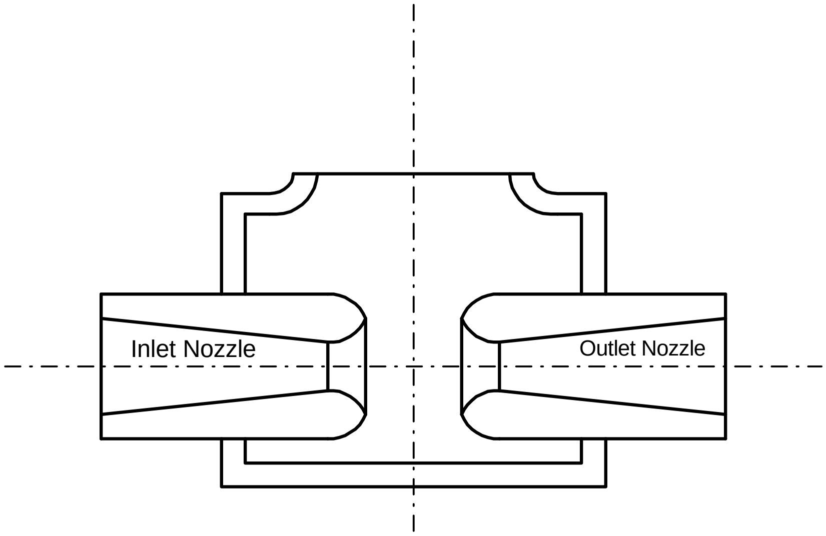


Figure 2.6-3. Basic RFD Design.



BASIC RFD DESIGN

Table 2.6-2. Reverse Flow Diverters

Fault	Important to Safety SSCs	Safety Function	Design Safety Feature
Overblow. An excessive drive phase can lead to air being blown through process liquor causing aerosol challenge to vessel ventilation system scrubber and filters.	Timers	To terminate drive phase before overblow	Fail-safe (closes drive value) Defense in Depth: Pressure control programmable system which constantly monitors pressure/time relationships and thus terminates drive and suction phases optimally. Its use is not certain and if used it would provide additional protection to that outlined for the timer system which is assumed
	Drive valve	To close on demand	Fails closed on loss of operating power
	Pressure regulator	To deliver pressure no greater than assumed in timer set-up	Regulator is locked in position after set-up Alarmed pressure transducer reveals deviation
	Needle valve	To regulate flow to no greater than assumed in pressure and drive time set up	Needle valve is locked in position after set up
Oversuck. Normal suction phase with vessel at low level can cause aerosol generation within the charge vessel to blow out through jet pump pair. This ultimately challenges the vessel vent system scrubber and filters.	Level measurement in vessel	To terminate suction phase before level low enough for oversuck	Alarm on low level
	Suction valve	To close on demand from level instrument	Fails closed on loss of operating power
	Primary isolation valve	Close on low vessel level. Isolates air to system to avoid overblow on next cycle	Fails closed on loss of operating power

Table 2.6-2. Reverse Flow Diverters

Fault	Important to Safety SSCs	Safety Function	Design Safety Feature
Overraise of active liquor out of primary shielding and confinement.	Position of jet pumps within cell	Maintain shielding and primary confinement	Design and construction change control Installation checking of locations the location of the pumps in cell above the liquor is more than the maximum lift height they can generate
Crossblow. Liquor is pulled into one jet pump and air liquor mixture blown out through the other causing increased aerosol challenge to the vessel ventilation system	Suction jet pump	To prevent radioactive liquids from being lifted into the jet pump	Set by design Tested during commissioning This is done by barometric head if possible, but if not depends on air flow and pressure control
	Pressure regulator	To deliver pressure no greater than used in commissioning set-up	Regulator is locked in position after set-up Alarmed pressure transducer reveals deviation
	Needle valve	To regulate flow to no greater than used in commissioning set-up	Needle valve is locked in position after set up.

2.6.3. Steam Ejectors

2.6.3.1. Purpose

Steam ejectors are used to transfer process liquids or to reduce the operating pressure of a system by gas removal. They are reliable, proven and require no in-cell maintenance.

Steam ejectors have a suction lift capability (i.e. they can empty liquid from vessels) and have a simple control system.

2.6.3.2. Description

A typical arrangement of a steam ejector system is shown in Figure 2.6-4.

High-pressure dry saturated steam is supplied to the steam ejector by an automated control valve. This steam is accelerated through a nozzle creating a differential pressure along a submerged suction leg within a vessel containing liquid sufficient to overcome the head required to lift the liquid up the suction pipe. This effect is known as striking. The steam then conveys the liquid to the destination vessel, normally via a breakpot. Control is established using level instrumentation in the vessel being emptied, and using temperature indication, such as a thermocouple, within the breakpot.

The design process for a steam ejector ensures that the pressure drop along the suction leg does not result in a final reduced pressure such that the liquid will boil within the leg.

Where steam ejectors are used to create a partial vacuum or reduced pressure, as in the TWRS-P evaporator circuits, the offgas process stream is driven by the same mechanism as for the liquid transfer from a vessel. The main methods of control will be an automated steam supply control valve, with pressure and temperature control.

2.6.3.3. Hazardous Situations

Normal operations of the steam ejectors does not require the achievement of any particular safety function. A number of fault conditions can however, place demands on other Important to Safety SSCs. Known fault conditions against which protection is required are:

1. Continued steam delivery after vessel is empty discharges active aerosol into the vessel ventilation system, challenging filters by active burden and potentially by moisture loading (wet filters will fail at lower delta P).

2. Steam condensing in supply line creates a vacuum which can potentially cause active liquor to be drawn out of shielding and primary confinement.

3. Reverse flows of liquor after steam isolation can cause elevation of liquor beyond starting elevations and so risk its rising above primary shielding and confinement.

The set of Important to Safety SSCs for the above hazardous situations (or faults) is provided in the following tables. The table also identifies the Safety function and the Design Safety Features.

Figure 2.6-4. Typical Arrangement of a Steam Ejector System

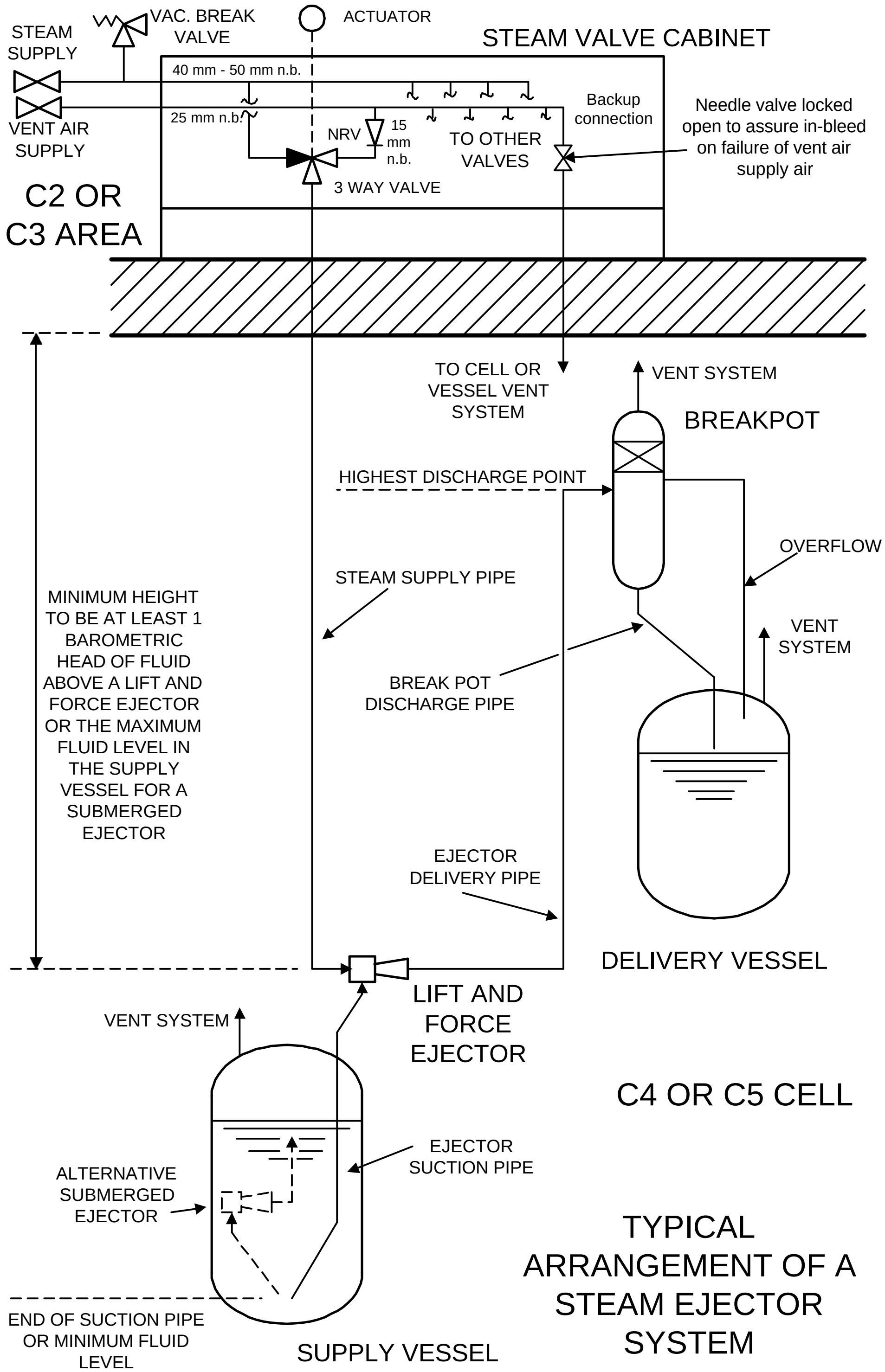


Table 2.6-3. Steam Ejectors

Fault	Important to Safety SSCs	Safety Function	Design Safety Feature
Continued steam delivery after vessel is empty discharges active aerosol into the vessel ventilation system, challenging filters by active burden and potentially by moisture loading (wet filters may fail at lower delta P)	Thermocouple in discharge breakpot	To detect excessive temperature indicating steam breakthrough	Fail-safe Excessive temperature is also alarmed to the operator to check valve closure.
	Trip valve	To isolate steam supply on detection of excessive temperature.	Valve fails closed on loss of operating power
Steam condensing in supply line creates a vacuum which can potentially cause active liquor to be drawn out of shielding and primary confinement.	3 way valve in steam supply line.	On isolation of steam supply, line between 3-way valve and ejector is automatically vented to vessel vent.	Valve fails to steam isolation and process line venting on loss of operating power. On loss of ventilation steam supplies are automatically isolated. Cabinet containing steam supply 3 way valve is located a barometric head above maximum liquor level.
	In bleed air supply to vent line.	To prevent activity being drawn back from vessel vent system to three way valve.	Loss of process air supply is alarmed.
	In bleed air supply to steam supply line	To prevent activity being drawn back from process line beyond three way valve in the event that an upstream isolation valve is closed before the three way valve	Valve is simple spring loaded poppet type one way valve.
	3 way valves are housed in a vented confinement.	Provides confinement barrier between C2 operating area and the 3 way valves	Confinement is under C5 depression. No routine access provisions exist. Disassembly under permit control is required for access.

Table 2.6-3. Steam Ejectors

Fault	Important to Safety SSCs	Safety Function	Design Safety Feature
Reverse flows of liquor after steam isolation can cause elevation of liquor beyond starting elevations and so risk its rising above primary shielding and confinement.	3 way valves are housed in a vented confinement which is located at an elevation above the discharge point	To prevent liquor rising out of primary shielding and confinement	Confirmation during commissioning
Blockage of steam ejector discharge nozzle can cause stream to be directed into the vessel via the suction leg. This can result in additional burden on the vessel vent system.	Vessel ventilation system	To prevent steam sparging of vessel contents causing activity to be transferred into vessel	Vessel ventilation scrubber (see Section 2.2.2 Vessel Vent).

2.6.4. Breakpots

2.6.4.1. Purpose

The main function of the breakpot is to reduce the amount of active material entrained into the vessel ventilation system. This reduces the effluent loading on the downsteam vessel ventilation treatment system together with a reduction of the activity levels existing in the vessel vent ductwork. Breakpots are provided on transfer lines that use steam ejectors for moving active liquors. These types of transfers give rise to the potential for higher entrainment of activity.

Breakpots also provide a secondary purpose in that for other transfer systems where siphoning could occur they provide a siphon break.

2.6.4.2. Description

A diagram of a breakpot is shown in Figure 2.6-5.

The breakpot is placed at a high point in the discharge line from the steam ejector. The breakpot receives a pumped liquid through an inlet nozzle located in its wall. The incoming liquid is directed towards a baffle. Within this section any non-condensed steam and gases disengage. The breakpot is self-draining and the liquid falls by gravity through the breakpot discharge pipe to the destination vessel.

Above the inlet nozzle(s) is a packed bed where disentrainment of the gas stream occurs. The exiting gas from the packed section passes into the vessel ventilation system. The packed bed can be washed periodically by a wash ring permanently installed above the packed bed. Within the packed bed a thermocouple located within a sheath to detect higher gas temperatures. This is an indication that the steam ejector is overblowing and not transferring liquid. The temperature alarm setting is specified such that transfer start up conditions (i.e., when there is an initial loading of steam into the breakpot) do not detect a fault condition.

2.6.4.3. Hazardous Situations

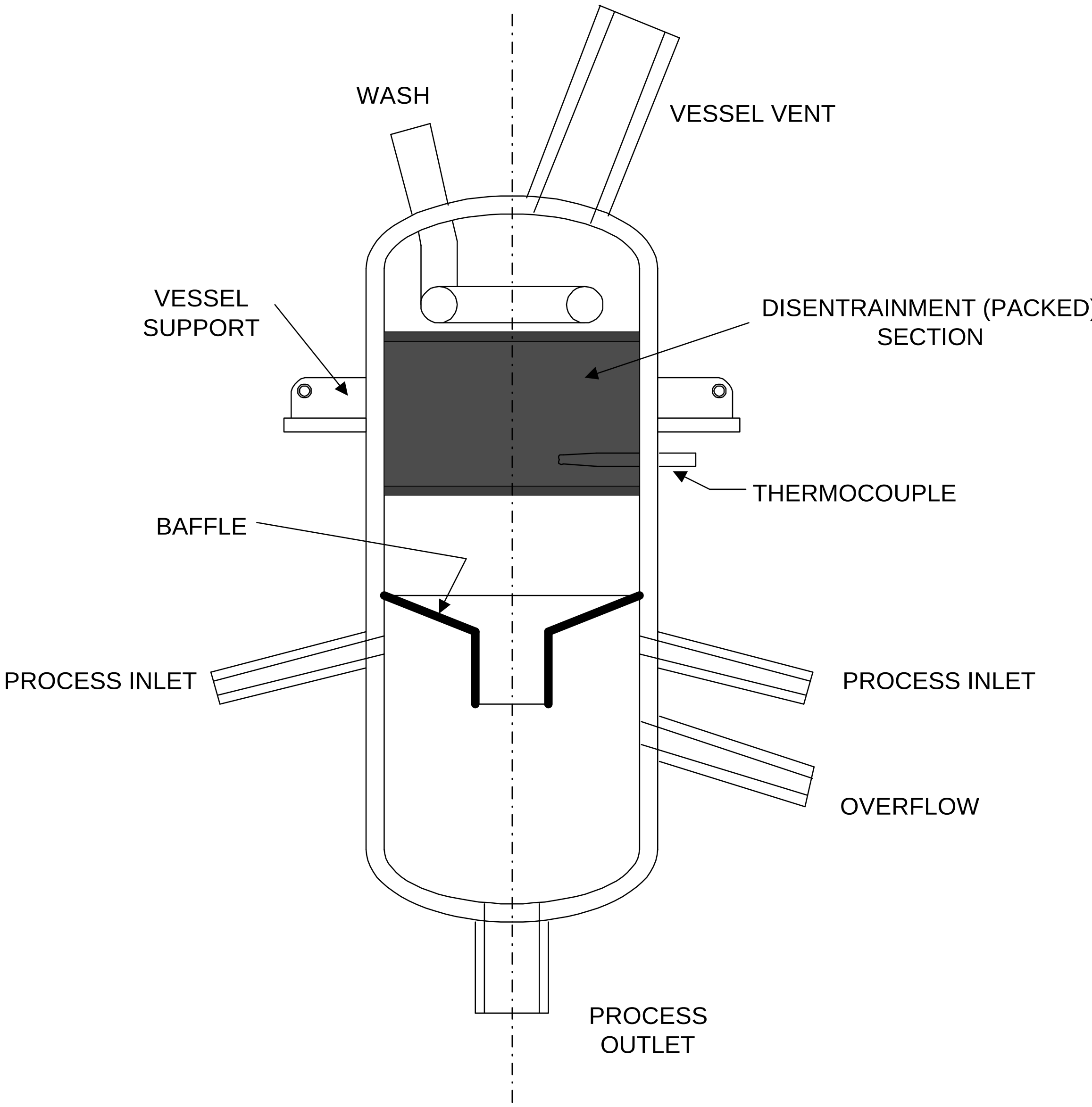
1. Carry over of aerosols into the vessel ventilation system leading to increased burden on the vessel ventilation system.

2. Misrouting of liquids through flooding leading to the potential for adverse chemical reactions (detailed review required).

3. Vessel erosion from the impingement incoming feeds onto the breakpot walls causing a breach of confinement

The set of Important to Safety SSCs for the above hazardous situations (or faults) is provided in the following tables. The table also identifies the Safety function and the Design Safety Features.

Figure 2.6-5. Breakpot.



BREAKPOT

Table 2.6-4. Breakpots

Fault	Important to Safety SSCs	Safety Function	Design Safety Feature
Carry over of active aerosols into the vessel vent system, challenging filters by active burden and potentially by moisture loading.	Packing within the tower section and diameter of the section below the inlet nozzles.	Disentrainment of the liquid and gaseous phases.	Effectiveness of disentrainment maintained by periodic washing of the packed bed.
Flooding of the breakpot causing liquor to be either misrouted through the feed nozzles or to the vent outlet.	Overflow pipe. Discharge pipe	To provide a supplementary outlet for incoming liquor To maintain adequate flowrate through the discharge line.	Pipe is sized for maximum incoming flow(s). Pipe is sized and configured to provide self-venting flow at the maximum incoming flow.
Vessel erosion.	Baffle	To protect the vessel walls from direct and localized impingement of incoming liquors.	Geometry and positioning of the baffle provides dispersion. Material selection of baffle plate.